AN EVALUATION OF SELECTION FACTORS FOR ANTLER GROWTH IN RED DEER (*Cervus Elaphus*)

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ABSTRACT

Fourteen male red deer (*Cervus Elaphus*) were studied over a period of 4½ years, to determine the effect of liveweight changes on antler growth. Significant positive relationships were found between liveweight and velvet antler yield both within and between antler growing seasons. Trends observed in this analysis indicate that liveweight at 16 months of age, could be an effective guide to the selection of superior antler producing stags at an early age.

CHAPTER 1

INTRODUCTION

Red deer (*Cervus elaphus*) are the most common of eight deer species introduced to New Zealand. Rapid establishment was induced by numerous liberations between 1851 and 1919. A wide range of congenial habitats were conducive to a rapid population increase. By the late 1920's red deer began to have deleterious effects on the indigenous forest vegetation. This prompted the removal of a protection policy and the implementation of a deer eradication policy (Harris, 1970; Whitehead, 1972; Harker, 1973).

Effective control of deer numbers was not successful until the early 1960's when the price of venison grew to such an extent that a commercial venison industry became viable. It became evident during the late 1960's that commercial hunting was having a large impact on deer populations (Challies, 1973; 1974). Reduction in deer numbers led to speculation as to the viability of the industry since large operations could not remain economic unless a regular supply of venison was maintained (Logan, 1970). Deer farming was foreseen as the possible answer to maintaining a very lucrative export trade.

Giles (1975) reports the complex negotiations which led to the amendment of deer control regulations and the issue of the first deer farming license in 1970. Attracted by high profits many farmers diversified into deer farming and subsequently the demand for breeding stock soared. Many of these ventures were based on selling farm-bred animals until the late 1970's when velvet antler also became a highly profitable trade.

During the 1979/80 season the value of live deer dropped sharply and the markets for velvet antler almost ceased. Although both events were unrelated, it seemed difficult to differentiate between the two (Yerex, 1980). Amongst a great deal of speculation as to the future of deer farming, it would appear that the industry is reliant on the development of a farmed venison trade. Markets for a limited quantity of velvet could be maintained, but quality restrictions must be introduced to maintain a market for a high quality product.

If farmers wish to continue in the production of velvet antler, they must identify and maintain a herd of superior antler producing stags. Since likely potential may not be assessed until three years of age, some early selection criteria would be desirable.

For this reason, analysis of data from trials run at Invermay, has been undertaken to determine which traits in young animals will indicate subsequent productivity of velvet.

CHAPTER 2

LITERATURE REVIEW

2.1 ANTLER GROWTH

2.1.1 INTRODUCTION

Antlers are exclusive to the male in red deer and although are often referred to as horns, they are structurally distinct. Literature relating to antlers is extensive but most is speculative and contradictive. A lot of variation occurs between species and during different stages of development which may account for much of the controversy (Chapman, 1975).

Considerable discussion has taken place on reasons for their evolution but as yet, there is no evidence firmly supporting any one theory in particular. Antlers are regrown annually in time for the rut, thus it has been suggested that their main role is related to sexual behaviour (Anthony, 1929; Henshaw, 1969; Lincoln, 1972; Chapman, 1975). However antlers are relatively ineffective weapons and are carried for a long period outside of the breeding season (Stonehouse, 1968).

Social ranking of deer within the herd affects competition for winter feed (Espmark, 1964; Chapman, 1975). Dominance is asserted by larger more aggressive stags using antlers as weapons or shields in defence. Clutton-Brook, Albon & Gibson (1979) reported that fighting involves appreciable costs, commonly in the form of antler breakages and more serious injury. Costly, strenuous battles are minimised by the advertisement of likely physical superiority. Antlers are important visual symbols and if removed by artificial or natural means result in a fall of social rank (Espmark, 1964; Lincoln, Youngsen & Short, 1970).

2.1.2 INITIATION OF GROWTH

Antlers are osseous appendages which develop from pedicles, the permanent extensions of frontal bones of the skull (Chapman, 1975).

Pedicles can be detected early in male foetal life (Lincoln, 1973) and develop during the first year under the influence of the developing testes (Chaplin, 1977).

Pedicles are cylindrical outgrowths situated on the skull above and behind the eyes (Noback, 1929). Antlers arise from the skin around and over the pedicle. There is little doubt that the bony tissue from which pedicles arise is important. If tissue of the frontal bone from which pedicles develop is removed, then pedicle and antler growth is inhibited (Goss, Severinghaus & Free, 1964). When this tissue is transplanted elsewhere on the skull, then a pedicle grows there, instead of the region for which it was destined (Goss, 1970).

After old antlers are cast, the extremity of the pedicle is exposed (Noback, 1929) (See Plate 1). A scab forms on the stumps of the pedicle and healing occurs by the migration of epidermis and subjacent tissue from the margins across the exposed pedicles. The new antler bud develops from the dermis of the pedicle skin, and within a few weeks forms a rounded knob growing on top of the pedicle (Goss, 1961) (See Plate 2).

Noback (1929) suggests that pedicles increase in diameter, but decrease in length with age. Indeed it would seem that the area from which antlers develop is larger in older or heavier antlered stags. Banfield (1960) has postulated a method for age determination using histological sections of pedicles. A preliminary study indicated the presence of annual rings during and after antler formation which may provide a method for age determination and assessing the nutritional level of a particular year.

2.1.3 STRUCTURE AND DEVELOPMENT

The antler is formed from connective tissue as cartilaginous trabecular which is converted into bony tissue during a mineralisation process (Molello, Epling & Davis, 1963; Banks, Epling, Kainer & Davis, 1968; Goss, 1970). Calcified osteoblasts, lay down additional bone in the

Plate 1: The exposed pedicle following antler casting

Plate 2: The velvet grows from the margins of the pedicles forming a rounded knob (2 weeks growth).

Plate 3: Developing antlers with branching of brow and bez tines (4 weeks growth).

Plate 4: "A" Grade velvet prior to harvesting (9 weeks growth).

shaft of the antler forming a rigid structure of spongy tissue surrounded by a wall of compact bone (Noback, 1929).

Growth is initiated by velvet which is an extension of the normal skin of the head which contains a rich supply of blood vessels and nerves (Noback, 1929). Branches of the superficial temporal artery ascend each antler through the pedicle providing a rich supply of blood to the velvet and supplying nutrients to the developing bone. Some arterial tributaries integrate profusely in the apices of the antler where rapid growth occurs. Veins accompany the arteries and empty into the superficial veins (Waldo, Wislocki & Fawcett, 1944).

Arterial transport between pedicle and antler diminishes rapidly as bone density increases (Waldo, Wislocki & Fawcett, 1944). Narrowing of the vascular channels restricts circulation until finally it ceases (Waldo *et al.*, 1944; Goss, 1970). When cartilage formation is complete and calcification of the tips occurs, the antlers are fully grown (Noback, 1929). The velvet dries and is shed leaving hard antler exposed (Goss, 1961).

The growing process of antlers occurs within a 3½ month period which includes casting and shedding of velvet. Thus, hard antlers are retained for 8½ months.

Prior to new growth the old antlers must be shed. Osteoclasts simultaneously destroy the narrow zone between antler and pedicle causing separation (Goss, 1970). Minute arterioles and venules persist in the antler connected to those of the pedicles, therefore some bleeding takes place at casting until a scab forms (Chapman, 1975). Thus, it suggests that the bone does not die completely when the velvet is shed, but mineralisation occurs for a few weeks after shedding (Hyvarinen, Kay & Hamilton, 1977) (See Plate 1).

Antlers consist largely of calcium, phosphorus and magnesium (Hillman, Davis & Abdelbaki, 1973; Chaplin, 1977) in a matrix of osteoid tissue

(Frandson, 1965). The annual growth and regeneration of antlers requires large quantities of these mineral salts to achieve composition similar to true bones (Motello, Epling & Davis, 1963; Modell, 1969), at growth rates in excess of any skeletal development known (Cowan, Hartsook & Whelan, 1969). These could not be supplied by the small quantities of minerals present in the diet (Chapman, 1975). The composition of antlers is presented in Table 1.

The large quantities of mineral metabolites required are obtained by internal bone remodelling which seems to occur despite available mineral reserves (Chapman, 1975). Resorption of cortical bone in the skeleton, particularly the ribs (Cowan, Hartsook & Whelan, 1968) is greatest during peak antler growth, but composition in skeletal bones and growing antlers remains constant (Banks, Epling, Kainer & Davis, 1968; Hillman, Davis & Abdelbaki, 1973). Rising levels of plasma calcitonin hormone levels could be responsible for the maintenance of constant bone calcium concentration during remodelling (Phillippo, Lincoln & Lawrence, 1972).

The activity of alkaline phosphatase generally associated with bone metabolism increases significantly during antler growth indicating that it may be a very important enzyme in antler formation (Graham, Rainey, Kulhman, Houghton & Moyer, 1962). Molello, Epling & Davis (1973) reported Ham (1954), as saying that alkaline phosphatase is essential in the Haversian systems of bone to prevent bone erosion. They postulated that the low levels of this enzyme at casting, may be mediating the breakdown of bone at the pedicle, causing separation of the antler.

2.1.4 PATTERN OF GROWTH

Red deer antlers are almost round in cross section. Each consists of a lightly pearled main beam from which branches a brow tine immediately above the coronet, a bez tine, and a trez tine. Royal tines which branch

TABLE 1: THE COMPOSITION OF SECTIONS OF THE ANTLERS OF 2-4 YEAR OLD STAGS AT GLENSAUGH DEER FARM AND AT THE ROWETT RESEARCH INSTITUTE* (standard errors in brackets)

	n	Ash	Ca	P	Mg
Glensaugh					
1972	5	590 (8.4)	231 (6.3)	109 (2.2)	3.21 (0.10)
1973	6	553 (16.2)	221 (6.8)	105 (3.5)	3.09 (0.09)
1974	5	562 (13.3)	227 (7.6)	105 (2.9)	2.97 (0.09)
Rowett					
1972-73	3	591 (21.7)	227 (10.9)	106 (2.8)	3.11 (0.11)

No significant difference was found between years at Glensaugh, nor between Glensaugh and Rowett stags

* Adapted from Table 2, Hyvarinen *et al.* (1977)

above the trez tine can take many forms (Harris, 1973) (see Fig. 1). However first and second head are commonly not so well developed as described by Harris, (1973). Antlers in the first year of growth are usually simple spikes which vary from small knobs to over 30cm in length. The second year growth is more complicated consisting of brow and trez tines with bez tines on either side seeming to be optional. It is the third set of antlers which seems to set the pattern for growth in mature stags, although they become heavier and may develop extra royal tines (Chapman, 1975; McNally, 1976).

The growth of antlers occurs during a three to four month period which begins (in New Zealand) at casting during September and October, then continues till the velvet is shed in January or February. Lincoln (1972) has observed that casting and hence velvet shedding, occurs earlier in older more dominant stags. The growth and differentiation of vascular elements within the antler tip is a rapid sequence which is possibly unique among animal tissues (Goss, 1970). A red stag in good condition can produce in excess of 9kg hard antler in less than a four month period. Growth is slow at first, then accelerates rapidly and finally slows down as maturation is approached (Goss, 1970). Thus if we consider that stags are capable of producing antlers over 100cm in length, (Harker, 1973) then we could assume that an estimate of peak growth rate at 1cm/day, was being conservative.

2.1.5 CONTROL OF ANTLER GROWTH

2.1.5.1 Photoperiod

The seasonal rhythm of antler replacement common to all temperate deer species is associated with the cycle of increasing and decreasing dayleng (Goss, 1969). Casting and subsequent growth of antlers is initiated by increasing daylength. Reversal of light rhythms will shift antler growth six months out of phase while antlers may not be replaced for several

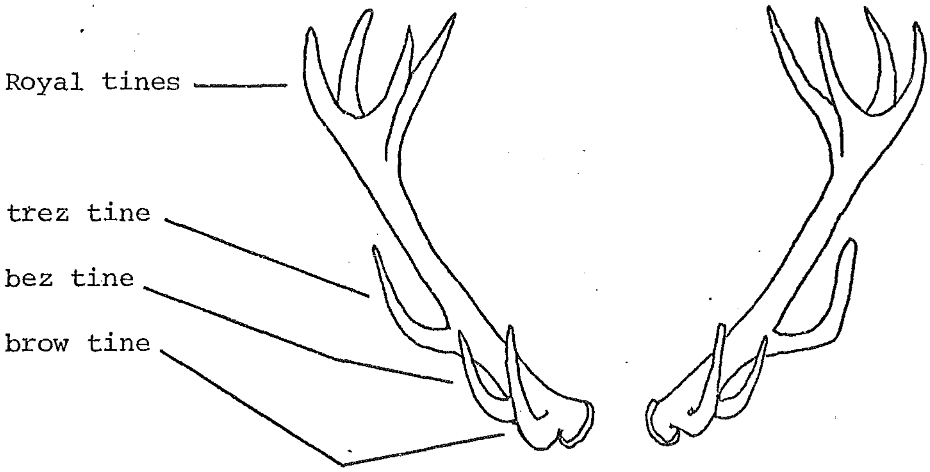


FIGURE 1: Typical antler formation in red deer

years in conditions simulating the equator (Goss, Dinsmore, Grimes & Rosen, 1974). This may explain the aseasonal pattern of reproduction in tropical species.

Goss & Rosen (1973) postulated that deer become entrained to natural photoperiod at puberty which regulates the antler cycle and seasonal changes in the level of testosterone. Stags become less responsive to certain artificial lighting conditions after first antler growth.

Wurtman & Axelrod (1965) suggest that the pineal gland acts as a mediator processing cyclic nervous activity generated by light, to cause hormone formation and release. However its role in deer has not been clarified. Pinealectomy in adult white tail deer (*Odocoileus virginianus*) described by Brown, Cowan and Kavanaugh (1978) had no affect on the antler cycle. They suggested that the cycle was entrained to environmental light and that the pineal gland only modifies the pattern ceasing to play a major function after puberty. This would seem to concur with the theory held by Goss & Rosen (1973).

2.1.5.2 Hormones

Annual sexual and antler cycles of deer are under the influence of circulating androgens controlled by the anterior pituitary and testicular glands. These glands control the process initiating growth, shedding and renewal of antlers (Wislocki, Aub & Waldo, 1947).

Pedicles, which are necessary for antler growth, develop in the presence of rising levels of testosterone (Wislocki, Aub & Waldo, 1947; Lincoln & Guinness, 1973; Chapman, 1975). Goss (1968) showed that castration of male fawns inhibits pedicle development and antler growth.

Antler growth occurs during an inactive period of testicular function. Rising levels of testosterone and spermatogenesis promote maturation and velvet shedding. Casting of old antlers occurs when testosterone secretion is minimal due to declining testicular activity (Wislocki, Aub & Waldo, 1947; Lincoln, Youngsen & Short, 1970; Chapman, 1975).

Most studies concerning the phenomenon of antler development have been related to the effects of castration and hormone therapy. Wislocki *et al.* (1947) demonstrated that castration of males after their first antlers have grown results in permanent retention of antlers in the "velvet" stage. Administration of testosterone into the peripheral circulation of castrated males accelerates calcification and velvet shedding, while casting is postponed in intact stags (Wislocki, Aub & Waldo, 1947; Lincoln, Youngsen & Short, 1970; Chapman, 1975). Lincoln *et al.* (1975) reports that castration of stags leaving the epididymis intact develops a more perfect set of antlers than a normal castrate, indicating that the epididymis is capable of releasing small amounts of androgens.

Abnormalities of genital organs such as hypogonadism lead to deer retaining their antlers in the velvet stage. Testes affected are aspermatogenic and diminish in size resulting in minimal testosterone secretion, thus the antler fails to calcify and velvet shedding is inhibited (Taylor, Thomas & Marburger, 1964).

Testicular activity is controlled by the anterior pituitary gland (Chapman, 1975). Lincoln (1971) found that the weight of the pituitary gland increases after antlers are cast, indicating that the gland is actively secreting hormones, and declines when velvet is shed. Releasing hormones from the hypothalamus stimulate the production of follicle stimulating hormone (FSH) and luteinizing hormones in the pituitary. Luteinizing hormone is responsible for testosterone secretion and FSH stimulates spermatogenesis (Chapman, 1975).

Investigations by Phillippo, Lincoln & Lawrence (1972) indicate that rising levels of hormone calcitonin in the thyroid coincide with increasing testosterone secretion. Peak levels of calcitonin could be responsible for the maintenance of a constant bone calcium concentration during the remodelling of bone that occurs during growth (Banks, Epling, Kaiher & Davis, 1968a, b). However the role of the thyroid and parathyroid which is responsible for calcium metabolism and blood calcium levels, has yet to be elucidated.

2.1.5.3 Nutrition

Some years seem highly favourable for antler growth while others seem highly unfavourable. Antler size increases with age and better feeding conditions or large deviations can be attributed to poor animal health (Huxley, 1926; Anthony, 1929; Chapman, 1975).

Young stags given winter supplementary feeding develop pedicles earlier than stags on lower planes of nutrition (Lincoln, 1971). Chapman (1975) cites Gillet (1904), who reported that a higher level of nutrition produces well branched antlers in the first season's growth which tend to be cast earlier. Body growth takes precedence over antler development in young growing deer (French, McEwan, Magruder & Ingram, 1955).

Earlier casting may result in faster growth of better developed antlers (Chapman, 1975). Stags which cast later tend to be in poorer condition (Watson, 1971; Chapman, 1975) which suggests that casting may be associated with nutritional levels.

Drummond, Greenwood, Ridgeway & Williams (1941) cite ~~reports~~ Vogt (1936), ~~that~~ a 50% increase in antler yield while was that was attained by feeding a calcium rich diet of sesame cake. Initially it was suggested that androgenic substances were responsible for spectacular results, but subsequent investigation by Drummond *et* did not support this hypothesis. Calcium and phosphorus deficient rations have caused decreases in antler size, but supplemented diets did not outproduce controls (French, McEwan, Margruder & Ingram, 1955). It would seem that increased development of antlers was due to correction of mineral deficient diets.

2.1.5.4 Animal Health

The effects of injuries on antlers has been the subject of much discussion but little investigation. Many deformities could be attributed to injuries of the pedicles or growing antlers (Clarke & Batchelor, 1972). Others have suggested that injuries to the skeleton can be correlated to the degree of antler deformity (Chapman, 1975). McNally (1976) postulated that the repair of damaged bone may take priority over the growth of new antlers. Loss of condition caused by severe injury may retard antler growth. However correlation between bodily injury and antler growth should affect each antler due to the nature of the body's vascular system so is not a logical explanation that only one antler is deformed (Chapman, 1975).

There is little evidence to support that parasitic infections cause antler deformities directly. Rather an indirect effect through nutrition and body condition is more plausible. High numbers of worms can interfere with normal digestive processes, making less protein available for the animals needs. The effect may be greater in young growing stags which have not built up any physiological resistance to the parasites compared to adults which develop an equilibrium between parasite and host (Moen, 1973).

2.2 LIVEWEIGHT CHANGES AND GROWTH RATES

Liveweight changes in deer are seasonal with weight losses occurring even when high quality feed is available. The growth period begins in early spring and continues for six months up to the breeding season when weight loss occurs. Large changes in body composition are possible because of the lean nature of deer. Hence a high proportion of liveweight change is protein and not energy "expensive" fat (Drew, 1976).

The seasonal nature of growth in farmed pasture fed stags has been reported by Moore & Brown (1977). Mean weaning weights of male calves at 3 months of age was 35kg. During the first winter a small weight gain of 45g/day was measured while weight was maintained during the second winter.

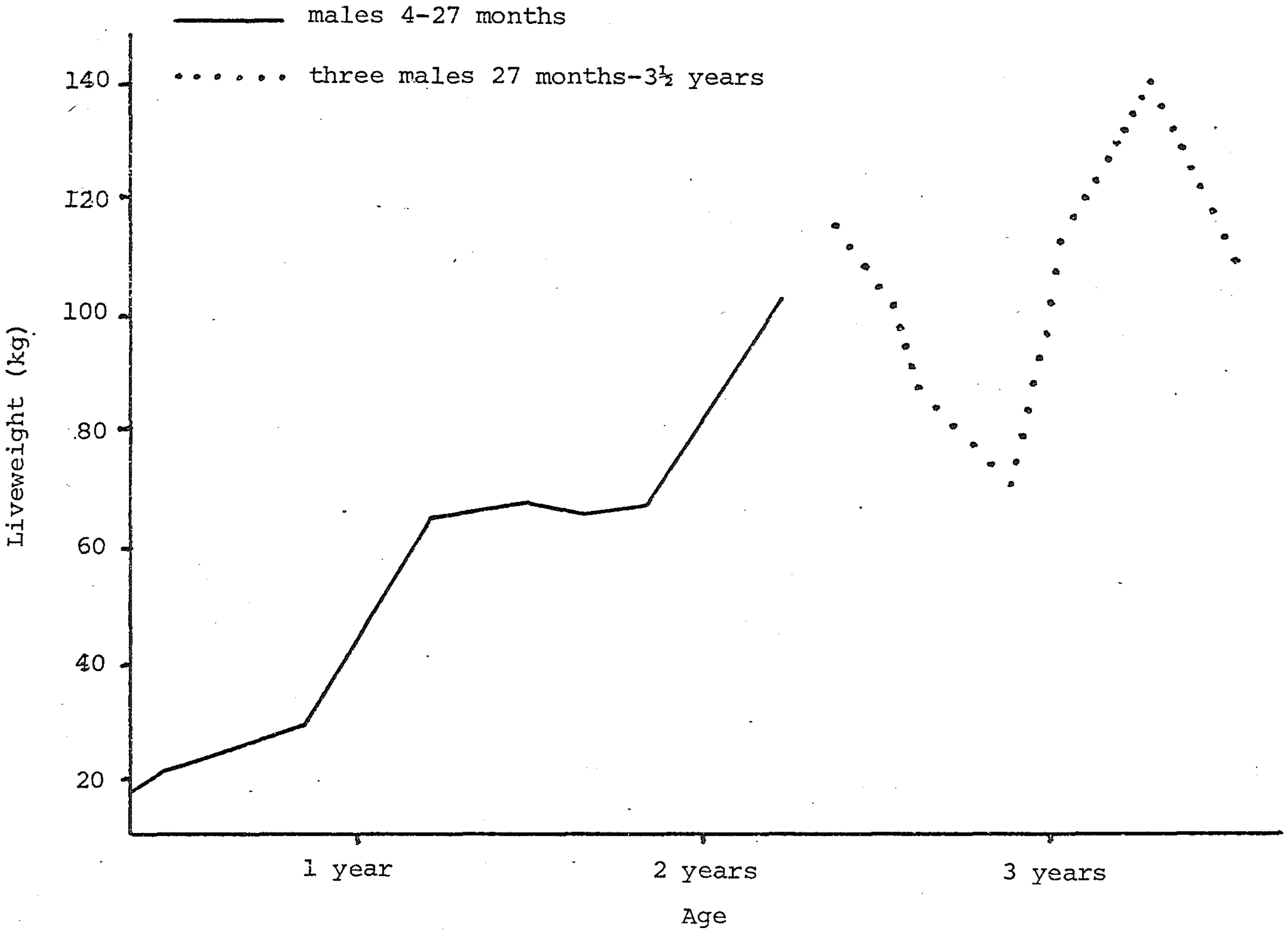
Growth rates during the first and second spring/summers were 260 and 275g/day respectively. Stags at 2 and 3 years of age gave weight losses of 10 and 20% over the rut while growth rates measured 900g/day during the first month post-winter (see fig. 2).

Lowered body condition associated with rutting activity occurs irrespective of reproductive success (French, McEwan, Magruder & Ingram, 1955; Gibson & Fuinness, 1980). Weight loss is partly due to inappetence as much as food availability (Blaxter, Kay, Sharman, Cunningham & Hamilton, 1974). Drew (1976) showed that intakes of feedlot deer given *ad libitum* rations were approximately 1.5kg DM/day during the breeding season but accelerated to 3.5kg DM/day in summer.

As the animal grows it does not simply increase in weight and size. The composition of gain also changes. Bone, which appears as the earliest maturing tissue is followed by muscle then fat (McDonald, Edwards & Greenhalgh, 1973). Skeletal development is largely complete by two years of age (Blaxter *et al.*, 1974). Drew & Greer (1977) have measured the carcass weights and composition of feral and farm fed stags at varying ages (see Table 2). Although there is little difference in protein content, the levels of fat rose noticeably. If stags are fed high concentrate diets it is possible to produce carcasses with fat levels as high as 15-25%, which approaches the levels found in "low fat" sheep and cattle (Blaxter *et al.*, 1974).

The most important factors which influence an animal population are those which regulate quality and quantity of feed (Challies, 1973). Deer seem to have adapted to the seasonal changes of their environment. Thus it seems they can stand short rations in winter despite having minimal fat reserves (Blaxter *et al.*, 1974).

FIGURE 2: Seasonal nature of growth in pasture-fed stags*



* Adapted from Figure 1, Moore & Brown (1977)

TABLE 2: STAG CARCASS WEIGHTS AND COMPOSITION*

Age (months)	Weight (kg)	Protein (% carc)	Fat (% carc)
Feral			
6	28.7	21.0	5.7
12	27.9	21.6	1.3
27	43.1	21.5	5.8
Grass-fed			
6	24.3	21.4	7.3
12	40.8	21.8	5.7
27	75.7	20.7	11.9

*Adapted from Table 2, Drew & Greer (1977)

2.3 ANTLER SIZE AND LIVEWEIGHT

The decline of many feral deer populations has been attributed to overstocking (Huxley, 1931; Challies, 1973; Challies, 1974; Nicholson, 1974; Short & Mann, 1979). Huxley has reviewed reports relating to the introduction of red deer into New Zealand. Body condition and antler size of the New Zealand bred deer were far superior to the parental stock. However as feeding areas deteriorated due to overstocking, the deer declined in condition. Harris (1970) suggests that deterioration in the available forage and interbreeding between strains produced heads of inferior quality and size.

Huxley (1931) postulated that liveweight gain was closely related to an increase in antler size. He presumed that high liveweight was achieved by stags in good body condition. Well nourished stags grow heavier and have larger antlers than those on a lower plane of nutrition (Hyvarinen, Kay and Hamilton, 1977). It was concluded that the size and composition of antlers could provide a useful method to monitor the growth and condition of stags.

Antler size is related to the size of deer both inter- and intra-specifically (Chapman, 1975). There is a positive allometric relationship between length of antlers and the height of shoulder in adult deer of the sub-family *Cervinae* (Gould, 1973).

Gould states that the giant deer, *Megaloceros giganteus*, of Pleistocene times, whose antlers have previously been considered too large for the size of the animal, fits this relationship.

Size and a complexity of antlers increase in succeeding years until the animal reaches it's prime. When the condition of the animal begins to decline between six and ten years of age, the antlers become less complex in structure (Chapman, 1975).

CHAPTER 3

EXPERIMENTAL

3.1 AIMS

The aim of this study was to determine whether early animal performance in young red deer could be used to predict likely superior antler producing stags. To achieve this objective, data which had been recorded over a 4½ year period at the Invermay deer research farm was analysed.

3.2 ANIMALS AND MANAGEMENT

An experimental herd of red deer was established at the Invermay Research Centre in 1973. Stock originated from two localities at (a) West Dome Station, Mossburn; and (b) Rahana Station, Taupo. The deer were run on two farms consisting of a hill country and flat first-class agricultural land. Pasture in both areas is dominantly mature perennial ryegrass and white clover with an approximate annual dry matter production of 8,000 and 10,000 kg DM ha^{-1} respectively (Kelly & Drew, 1977).

Forty-four male red deer were born during December 1975 and January 1976 on the hill country farm. Birth dates of seven calves reported in this study were recorded from 3 December to 9 January. The amount of birth information recorded was limited because it was felt that human interference might disturb the breeding herd resulting in mis-mothering of calves. The calves were weaned in early April, eartagged and liveweight recorded then transferred to the flat, more fertile land.

During March to September 1976 the animals were part of an experimental investigation on the effects of gastrointestinal parasites in red deer. Throughout the trial faecal egg counts and parasite counts in 12 slaughtered deer were consistently low. Therefore no significant difference due to anthelmintic treatment was recorded (Mason, 1977).

Following indications of a copper response in antler growth at a South Canterbury deer farm, a trial was carried out during October 1976 with the administration of copper glucinate. Serum copper levels were increased 50% in treated stags but differences in liveweight gain or velvet yield were not significant (Fennessy, pers. comm.).

From September 1976 to March 1977 the stags were run in an experimental grazing trial and were stocked at 30.7 stags ha^{-1}. Liveweight gains and carcass production figures from eight slaughtered stags recorded during the six month period have been published by Drew & Greer (1977).

Ralgro (zeronol) was implanted in the necks of 10 stags just prior to casting in October 1977 (12 mg/stag). Antler casting was retarded in all animals, and 3 stags failed to cast and grow antlers in that year. Treated stags produced lower yields of velvet antler, but were 3kg of liveweight heavier than controls (Moore, 1978).

Six stags died during the recording period of this trial and two were slaughtered when they became dangerous during handling. Liveweight changes and velvet antler production were continued at regular intervals during the 4½ year period on the remaining 14 stags. The stags were run on the flat area during the spring/summer and wintered on the hill country farm.

3.3 FEEDING

From weaning to 15 months of age the stags were rotated around the pastures on the flat area and were supplemented with lucerne hay during the winter.

In following seasons the stags were wintered on the hill farm but were transferred to the flat area for the velvet growing and harvesting period. During the winter pasture was supplemented with meadow hay, small quantities of deer nuts and whole barley.

Some nuts were fed during the velvet growing period to keep the animals quiet and easy to handle.

3.4 LIVEWEIGHT CHANGES

The deer were weighed at regular intervals to determine liveweight changes, monitor animal condition and health. Liveweight changes are presented in Figure 3.

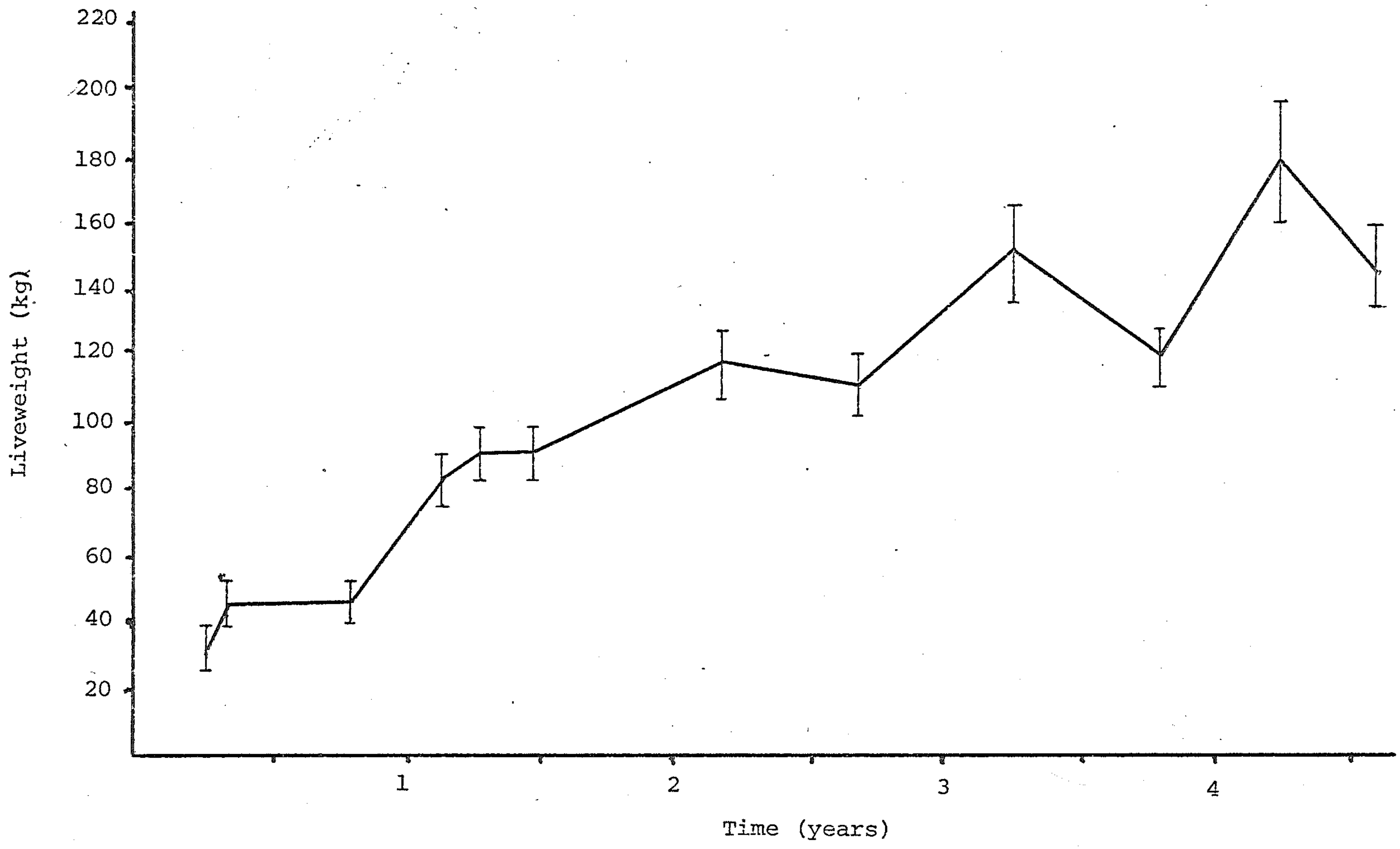
3.5 ANTLER HARVESTING

Velvet antler was removed every 7 days from yearling stags (spikers), once calcification of the tips was evident. Antlers were removed with cattle dehorners approximately 2½ cm above the pedicle and antler junction. Variation between the stage of antler development in stags at removal was possible.

During antler growing seasons of year 2, year 3 and year 4, all stags were assessed every two days for a standard stage of growth, required for an A grading on the velvet antler market. It can be described as the stage prior to branching of the royal tines before hard antler formation (see plate 4).

Removal of velvet antler from deer over the age of twenty months requires the administration of an anaesthetic. Therefore 5% Rompun (Bayer Pharmaceuticals) at a dose rate of 1 ml/100 kg of liveweight was injected intramuscularly. This dose was increased for stags with more excitable temperaments. A local anaesthetic 10% Xylocaine (Astra Chemicals) was injected into two sites blocking the nerve supply of the infatrochlear and zgomaticotemperal branches of the ophthalamic division of the trigeininal. This method is similar to that used for dehorning goats (Vitums, 1954) and has been reviewed for deer by Adams (1979). The deer were not completely anaesthetized so that antlers could be sawn off with the stag in a standing position. A simple tourniquet was applied to the outer periphery of the pedicles which is necessary for rapid coagulation of severed blood vessels after cutting. Two operators were required for the operation, one for cutting and the other to restrain the head of the stag

FIGURE 3: Liveweight Changes



preventing any sudden movement which may lead to antler damage. A hack saw was used to remove the antler 1 cm above the pedicle.

After removal, the antlers were hung upside down to prevent any blood draining from them before weighing.

3.6 CASTING DATES

Although most of the antler is removed at harvesting, the base of the antler left attached to the pedicle matures into bony antler. Before growth of new antlers begins, this attachment must be cast similar to a fully grown antler. Records were kept daily when each stag cast these antler stubs, as an indication of normal antler casting procedure.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

A summary of the regression analyses carried out on factors likely to affect liveweight gains and velvet antler yield has been presented in appendix 11. All significant relationships were positively correlated, except for the initiation of antler growth during the first year, or at casting in succeeding years which gave negative regression coefficients. It appears that liveweight is related to antler size, but interpretation of its influence is complicated by large changes in body condition and size indicated in figure 11. This relationship has also been suggested by Huxley (1931).

4.2 VELVET ANTLER YIELD

Velvet antler weights recorded during the study period have been presented in appendix 1. Yields from year 2 have been omitted from the analysis in appendix 11 because they were affected by ralgro treatments (see appendix 1).

It has been suggested (section 3.5) that assessment of the stage of growth in the first antlers was not consistent. This seems to be reflected in a poor relationship between the first velvet antler yield, and corresponding yields from the same stags in later seasons (see regressions 12-13). However there is a strong relationship ($P < 0.01$) between the weights of velvet antler recorded in year 3 and year 4 (see regression 14).

From these results it would seem that velvet antler yields between seasons could be correlated, but the influence of the first season's antler growth on later velvet antler production has not been clearly proven in this analysis. Thus, if a significant positive correlation between these factors exists, then superior antler producing stags could be selected on the first season's antler yields. However, accurate assessment of antler yield would be required during the first season of antler growth.

4.3 INFLUENCE OF LIVEWEIGHT AND LIVEWEIGHT GAIN ON VELVET ANTLER YIELD

Weaning liveweight was correlated with birth date (see regression 1) and is likely to be a function of the milking ability of the dam. It did not appear to be a factor influencing velvet antler yield. Interpreting liveweight changes during the first year is difficult, since they are affected by the maternal factors which largely determine weaning liveweight. These factors are not so evident as the animals grow after weaning and express their genetic potential. Thus, it suggests that the factors which influence liveweight during this early stage may not necessarily affect velvet antler yield.

Liveweight at casting showed a significant relationship with antler yield at the 5% significance level during year 3 and the 1% significance level during year 4. Average liveweight during antler growth and liveweight at the harvesting of the antlers have a highly significant positive relationship with velvet antler yield. Statistically it appears that liveweight at harvesting is a more reliable prediction of velvet antler yield than liveweight at casting during year 3. Similar trends also occur in year 4, however the differences may not be statistically significant.

Antler growth occurs during a period of rapidly increasing bodyweight when the stags compensate for body condition lost during the preceding winter. The ability to lose and gain weight increases with age (see figure 3) and would appear to be related to the size of the stag. Larger stags which reach peak liveweight at the end of spring and summer growth, tend to lose a higher proportion of their bodyweight in the following autumn and winter seasons. Therefore, liveweight at the harvesting date is more closely related to peak liveweight than weights recorded earlier in the antler growth period. Earlier liveweights may not be highly correlated to the liveweight potential of the large stag which emerges from the winter in poorer body condition than a smaller stag.

Liveweight gains during the antler growing period were compared to velvet antler yield from the same periods. The relationships appeared to be significant at the 5% level in year 3 and the 1% level in year 4 (see regression 27, 37). This would indicate that if stags with the highest liveweights at harvesting produce the best yields of velvet antler, they also show the largest changes in liveweight. Daily liveweight gain during antler growth was not significantly related to velvet antler yield in year 3 and was significant at the 5% level in year 4.

Thus, the results indicate that liveweight gain was not an important factor influencing better antler yields. The significance of liveweight gain relationships reflected the changes in liveweight of bigger stags, which tend to yield more velvet antler.

4.4 RELATIONSHIP BETWEEN EARLY LIVEWEIGHT AND LATER LIVEWEIGHT

Liveweight parameters which had shown a significant relationship to velvet antler yield within the 3rd and 4th antler growing seasons were compared to liveweights and liveweight gains from weaning to 16 months of age. The results are presented in appendix 11 (regressions 44-73).

Liveweight at 16 months of age gave the most consistent and significant positive relationships (see regressions 70, 71, 73). This measurement was recorded when the stags are in peak condition prior to the breeding season and the winter period when body condition is lost. It is significant that this relationship agrees with other trends shown in this analysis since this measurement is likely to express the growth potential of the stag.

Assessing the likely potential of stags at 16 months of age would be advantageous. Firstly, it follows the harvesting of the first antlers, and secondly it presents the stags in top body condition for sale or slaughter. It is desirable that a method be devised for assessing the first antlers of stags which correlates with later production. This factor and liveweight information at 16 months of age could be combined to enable a more accurate prediction of the likely potential for velvet antler yield in mature stags.

Since velvet antler harvested from yearling stags is relatively valueless, the antlers could be removed in "hard horn" when the velvet is shed. This would ensure that assessment takes place on antlers at the same morphological stage of development. However, the practical implications of handling antlered stags would necessitate careful managmment.

4.5 INFLUENCE OF CASTING DATE ON VELVET ANTLER YIELD

It has been suggested that stags which cast earlier in the season produce heavier antlers (Fennessy, pers. comm.) and tend to be in better body condition. Therefore it was thought that by increasing the nutritional level of stags, that they may cast earlier and produce higher yields of velvet antler. This factor is being investigated by workers at the Invermay Research Centre and at Lincoln College. Results so far indicate that casting date can be advanced, but it may not increase velvet antler yields significantly (Fennessy, pers. comm.).

Analysis of casting date in this study showed significant relationships with velvet antler yields within year 1 ($P < 0.10$) and year 3 ($P < 0.05$). This relationship was not significant in year 4 (see regressions 21, 24, 34). These results indicate that casting date does not influence antler size, but may be affected by factors which also affect antler growth.

Larger stags which tend to be higher in the hierarchical structure of the herd, compete more successfully for access to better grazing and feed supplements. It is likely that these animals regain body condition faster and hence may cast earlier. It seems coincidental that most stags which cast early are stags which reach the highest liveweights and hence produce the best velvet antler yields. This may account for the positive relationships in year 1 and year 3 but does not explain the insignificant result in year 4. However, casting date occurs earlier as the stags mature (see appendix 111). Therefore, liveweight at casting during year 4 is more likely to resemble the winter liveweight of the stag. In comparison casting during year 3 may occur up to 5 weeks later in the season. Hence, liveweights recorded at casting are more closely related to peak liveweight in year 3 than year 4. It has already been shown that liveweights which are closely related to peak liveweights give the best relationships to velvet antler yield.

CHAPTER 5

SUMMARY

This study, which analysed data collected over a period of 4½ years, indicates that there are significant positive relationships between liveweight and antler growth. There was a positive relationship between two years mature velvet antler yields and these may also have had a positive relationship with early antler weights. Early liveweights are positively related to later liveweight and mature velvet antler yields. Using these parameters, it is suggested that liveweight at 16 months of age could be used as an effective guide to selecting superior antler producing stags at an early age. This selection may be assisted by also taking into account antler size during the first year, but this would require further investigation.

Effects of body condition and casting date did not appear to affect velvet antler yields in this analysis. However, it must be stressed that only 14 animals were available for analysis, and so the statistical significance of the relationships could be challenged.

Relative to previous studies on the relationship between liveweight and antler size, the analysis in this compilation is significant despite the small numbers of experimental animals.. The reason for this being that many intensive measurements have been recorded on the same animals under similar conditions. It is likely that the significance of factors discussed will be clarified as deer research on an intensive basis increases.

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APPENDIX I: VELVET ANTLER PRODUCTION

Animal No	Year 1	Year 2	Year 3	Year 4
1	282	952+	1619	1854
2	192	0+	1535	1313
3	361	1125	1795	1840
4	261	903	1223	1754
5	164	725	1167	1405
6	301	0+	1150	1391
7	123	659	1422	1548
8	262	0+	1760	1862
9	129	551+	1276	1619
10	281	985	1441	1897
11	93	605+	849	1238
12	254	680+	1162	1205
13	220	782	1146	1284
14	*	659	1199	1251

Note: * Velvet Antler not harvested

+ Ralgro treated stags

APPENDIX II: SUMMARY OF REGRESSION ANALYSIS

(a) Influence of birth date+ on performance year 1

Regression	Dependent Variable Y	Independent Variable X	Regression Significance**
1	Liveweight at Weaning	Birth Date	**
2	Winter Liveweight	Birth Date	**
3	Liveweight at "Budding" of First Antlers	Birth Date	N.S.
4	Liveweight at Harvesting of Velvet Antler	Birth Date	**
5	Velvet Antler Weight	Birth Date	N.S.
6	Liveweight Gain During Antler Growth	Birth Date	N.S.
7	Liveweight at 16 months	Birth Date	*

Note: + mean of seven stags only

** = ($P < 0.01$)

* = ($P < 0.05$)

N.S. = ($P > 0.10$)

APPENDIX II: cntd

(b) Comparison of antler growth between seasons

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
8	Casting Date Year 3	Date of Budding of first antlers	($P < 0.10$)
9	Casting Date Year 4	Date of Budding of first antlers	($P < 0.10$)
10	Velvet antler weight Year 3	Date of Budding of first antlers	N.S.
11	Velvet antler weight Year 4	Date of Budding of first antlers	N.S.
12	Velvet antler weight Year 3	Velvet antler weight Year 1	($P < 0.10$)
13	Velvet antler weight Year 4	Velvet antler weight Year 1	($P < 0.10$)
14	Velvet antler weight Year 4	Velvet antler weight Year 3	**

Note: ** = ($P < 0.01$)

* = ($P < 0.05$)

N.S. = ($P > 0.10$)

APPENDIX II: cntd

(c) Liveweights and velvet antler production during year 1

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
15	Date of Budding of first antlers	Weaning Liveweight	(P < 0.10)
16	Winter Liveweight	Weaning Liveweight	**
17	Liveweight at 16 months	Weaning Liveweight	*
18	Velvet antler weight	Weaning Liveweight	N.S.
19	Velvet antler weight	Winter Liveweight	N.S.
20	Date of Budding of first antlers	Winter Liveweight	(P < 0.10)
21	Velvet antler weight	Date of Budding of first antlers	(P < 0.10)
22	Velvet antler weight	Liveweight gain during antler growth	N.S.
23	Velvet antler weight	Liveweight at harvesting of velvet antler	N.S.

** Note: ** = (P < 0.01)

* = (P < 0.05)

N.S. = (P > 0.10)

APPENDIX II: cntd

(d) Liveweights and velvet antler production during year 3

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
24	Velvet antler weight	Casting Date	*
25	Casting Date	Liveweight at Casting	N.S.
26	Velvet antler weight	Liveweight at Casting	*
27	Velvet antler weight	Liveweight gain during antler growth	*
28	Velvet antler weight	Daily liveweight gain during antler growth	N.S.
29	Velvet antler weight	Average liveweight during antler growth	**
30	Velvet antler weight	Number of days growth	(P < 0.10)
31	Velvet antler weight	Liveweight at harves-ting of velvet antler	**
32	Velvet antler weight	Liveweight gain spring/summer	**
33	Casting Date	Liveweight gain spring/summer	N.S.

** Note: ** = $(P < 0.01)$

* = $(P < 0.05)$

N.S. = $(P > 0.10)$

APPENDIX II: cntd

(e) Liveweights and velvet antler production during year 4

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
34	Velvet antler weight	Casting Date	N.S.
35	Casting Date	Liveweight at casting	(P < 0.10)
36	Velvet antler weight	Liveweight at casting	**
37	Velvet antler weight	Liveweight gain during antler growth	**
38	Velvet antler weight	Daily liveweight gain during antler growth	*
39	Velvet antler weight	Average liveweight during antler growth	**
40	Velvet antler weight	Number of days growth	**
41	Velvet antler weight	Liveweight at harvet- ing of velvet antler	**
42	Velvet antler weight	Liveweight gain spring/ summer	N.S.
43	Casting Date	Liveweight gain spring/ summer	**

** Note: ** = ($P < 0.01$)

* = ($P < 0.05$)

N.S. = ($P > 0.10$)

APPENDIX II: cntd

(f) Influence of early liveweight on later liveweight

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
44	Liveweight at casting Year 3	Weaning Liveweight	(P < 0.10)
45	Liveweight gain during antler growth Year 3	Weaning Liveweight	N.S.
46	Liveweight at harvesting Year 3	Weaning Liveweight	N.S.
47	Liveweight at casting Year 4	Weaning Liveweight	N.S.
48	Liveweight gain during antler growth Year 4	Weaning Liveweight	N.S.
49	Liveweight at harves-ting Year 4	Weaning Liveweight	N.S.
50	Liveweight at casting Year 3	Winter Liveweight	**
51	Liveweight gain during antler growth Year 3	Winter Liveweight	N.S.
52	Liveweight at harves-ting Year 3	Winter Liveweight	*
53	Liveweight at casting Year 4	Winter Liveweight	N.S.
54	Liveweight gain during antler growth Year 4	Winter Liveweight	*
55	Liveweight at harves-ting Year 4	Winter Liveweight	(P < 0.10)

** Note: ** = (P < 0.01)

* = (P < 0.05)

N.S. = (P > 0.10)

APPENDIX II: cntd

(g) Influence of early liveweight gain on later liveweights

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
56	Liveweight at casting Year 3	Liveweight gain from weaning to end of winter	N.S.
57	Liveweight gain during antler growth Year 3	Liveweight gain from weaning to end of winter	N.S.
58	Liveweight at harvesting Year 3	Liveweight gain from weaning to end of winter	N.S.
59	Liveweight at casting Year 4	Liveweight gain from weaning to end of winter	N.S.
60	Liveweight gain during antler growth Year 4	Liveweight gain from weaning to end of winter	N.S.
61	Liveweight at harvesting Year 4	Liveweight gain from weaning to end of winter	N.S.
62	Liveweight at casting Year 3	Liveweight gain during spring/summer	N.S.
63	Liveweight gain during antler growth Year 3	Liveweight gain during spring/summer	$(P < 0.10)$
64	Liveweight at harvesting Year 3	Liveweight gain during spring/summer	*
65	Liveweight at casting Year 4	Liveweight gain during spring/summer	**
66	Liveweight gain during antler growth Year 4	Liveweight gain during spring/summer	N.S.
67	Liveweight at harvesting Year 4	Liveweight gain during spring/summer	**

** Note: ** = $(P < 0.01)$

* = $(P < 0.05)$

N.S. = $(P > 0.1)$

APPENDIX II: cntd

(h) Influence of liveweight at 16 months of age on later liveweight and velvet antler yield

Regression	Dependent Variable Y	Independent Variable X	Regression significance**
68	Liveweight at casting Year 3	Liveweight at 16 months	N.S.
69	Liveweight gain during antler growth Year 3	Liveweight at 16 months	N.S.
70	Liveweight at harvesting Year 3	Liveweight at 16 months	*
71	Liveweight at casting Year 4	Liveweight at 16 months	**
72	Liveweight gain during antler growth Year 4	Liveweight at 16 months	N.S.
73	Liveweight at harvesting Year 4	Liveweight at 16 months	**
74	Velvet antler weight Year 3	Liveweight at 16 months	**
75	Velvet antler weight Year 4	Liveweight at 16 months	*

Note: ** = $(P < 0.01)$

* = $(P < 0.05)$

N.S. = $(P > 0.10)$

APPENDIX III: CASTING DATES

	Casting Dates		
Animal No.	Year 2	Year 3	Year 4
1	25.11.78+	16.10.79	21. 9.80
2	* +	7.10.79	14. 9.80
3	23.10.78	10.10.79	14. 9.80
4	31.10.78	11.10.79	29. 9.80
5	2.11.78	23.10.78	24. 9.80
6	* +	26.10.79	23. 9.80
7	2.11.78	11.10.79	22. 9.80
8	* +	4.10.79	11. 9.80
9	4.11.78+	30.10.79	10.10.80
10	1.11.78	10.10.79	19. 9.80
11	7.11.78+	30.10.79	15.10.80
12	2.11.78+	19.10.79	3.10.80
13	16.10.78	24. 9.79	11. 9.80
14	14.11.78	11.11.79	9.10.80

Note: + Ralgro treated stags

* Stags did not cast